[Proc. Roy. Soc. Victoria, **41** (N.S.), Pt. II., 1929.]

Art. XII.—*The Geology and Palaeontography of the Cathedral Range and the Blue Hills, in North-Western Gippsland.*

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(With Plates XVII., XVIII.)

[Read 13th December, 1928; issued separately 3rd April, 1929.]

Summary.

1. The Cathedral Beds, formerly believed to be of Upper Palaeozoic age, are demonstrated to be of pre-Upper Devonian, and probably of Upper Silurian age.
2. The western edge of the large area of igneous rocks which contains Mt. Torbreck and the Cerberean Ranges, is shown to consist of Upper Devonian rocks, mainly rhyolites, and these are shown to occur to an unknown extent to the east.
3. A newly discovered fish fauna from the Upper Devonian is described.
4. Silurian fossils from a new locality are listed, and a new stelleroid noticed.

Introduction.

Location.

The area studied is a roughly rectangular block of country stretching, along its western boundary, from Buxton to Taggerty, a distance of seven miles. It extends eastwards for five and a half miles from Taggerty, and three and a half miles from Buxton, and consists mainly of the southern two-thirds of the Parish of Taggerty, in the County of Anglesea.

The location was suggested in December, 1927, by Professor Skeats, as likely to reveal the relations between the Cathedral Beds (supposed Upper Devonian or Lower Carboniferous), and the dacites (supposed Lower Devonian).

The latter are, however, not present in the area, and the Cathedral Beds appear to be Silurian in age, while the supposed dacites are Upper Devonian rhyolites.

Previous Workers.

The amount of previous work done in this area is extremely small. In 1899 W. H. Ferguson reported as follows after a very rapid examination: "The rocks are layers of coarse and moderately coarse-grained sandstones, with some shales . . . the sandstones . . . contain a few well waterworn pebbles. . . . Ripple markings and filled-in desiccation cracks were noted. In some of the coarse-grained sandstones spots of very fine sedimentary rock were seen. . . . No fossils were found in the sandstones of the Cathedral Mountain, which is three or four miles in length. The rocks near this mountain are Upper Silurian porphyries, slates and sandstones. No clear contact could be found showing the relation of the Silurian rocks to the Cathedral sandstones, but the general lithological inference is that the Cathedral rocks are younger than the Silurian, and probably of Upper Palaeozoic age, Upper Devonian or Lower Carboniferous. On the east the sandstones join the fragmental porphyry formation at the Little River. These rocks, in other parts of the colony, have been referred to Upper Palaeozoic age." (Ferguson, 1899).

On this evidence, the Cathedral sandstones were coloured as Upper Palaeozoic on the Geological Map of Victoria, an inch to 8 miles, published later by the Survey.

Professor J. W. Gregory probably visited the area, and he published his idea of the structure in his handbook on the Geography of Victoria (Gregory, 1912, p. 72), showing the Cathedral sandstones as older than the volcanic rocks, which he believed to be dacites, and thought to be of Tertiary age. A rock section [400] at the Geology School is labelled " Dacite: Between Chapel Hill and the Cerbereans," and was probably collected by him. It is not, however, a dacite, but a section of the main rhyolite flow.

Professor Skeats (1910) writes, following Gregory:—" The map indicates a great mass of granitic rocks extending from near Narbethong, through Marysville, north-east to Mount Torbrech, whereas over most of this area the rock is certainly dacite." The granitic rock at Buxton is coloured as such by the Survey. The only other relevant record of geological work the author could find is a report by Dunn (1907) on gold and tin workings just outside the area here considered, and dealing with Silurian sediments only.

PHYSICAL FEATURES.

The area is one of strong, even precipitous, relief. The Cathedral Range runs in a general SSE. direction from the Cathedral to the Sugarloaf (see map), and is a composite hogback grading to a razorback, with the dip slopes (often bare sandstone) to the east, and the escarpment on the west. There the slopes are covered with thick talus, and in profile this presents a curve of great beauty.

The crest of the range is determined by the outcrops of two beds of hard sandstone, extending the whole seven miles, and separated by soft shales. At the northern end the highest ridge, with the Cathedral Mount, is formed by the lower standstone, while in the south the highest ridge, with the Sugarloaf, is formed by the upper sandstone dipping easterly at 65°, and constituting a razorback. The trough-shaped subsequent valley between the sandstones is called the Tableland. It is well grassed, and is used as a sheep run.

In the valley west of the Cathedral Range the Acheron River flows northwards to the Goulburn, while the valley east of that Range is occupied by the Little River, flowing north-north-west and later west to join the Acheron at Taggerty. The western boundary of the area studied is marked by the crestline of the Blue Hills, a range higher than the Cathedral Range, running generally NNE.-SSW. The slopes of this range are covered with rounded rhyolite boulders in the upper parts, but become clearer on the Silurian lower down. Chapel Hill lies in the traingle between the Little River and the Blue Hills. Immediately to the east of Buxton a resistant granodiorite-porphyrite has determined the formation of a steep and, especially at its southern end, high ridge. The river flats are swampy.

Nature of the Present Survey.

The combination of steep bouldery slopes, sometimes precipitous, dense growths of bracken, and in the gullies, tangled fern flora, made the work of surveying without a companion both arduous and difficult. The boundary of the Upper Devonian north-east of the Little River, the Buxton granodiorite, the Little River alluvium (where shown on the map), and a small but important area east of the Sugarloaf were traversed by compass, distances being paced. The Cathedral Beds were mapped approximately by radiations from fixed points on the main road, in the absence of a reliable method of measuring distances up steep slopes, and the talus from the Cathedral Range was marked in from sketches of the range. The outcrops on Chapel Hill, the talus from the Blue Hills, and the boundary of the Silurian to the east of Buxton, were sketched in from a knowledge of the country from memory, with the help of notes and sketches. The Lands Department's parish plans on a scale of 2 inches to the mile were used as the basis for all work.

Geology.

Yeringian (Upper Silurian).

1. *Typical Silurian.*

Shallow marine Silurian mudstones, sandstones and shales occur both in the north and the south. Fossils were found near the foot of the Blue Hills, in red sandstones showing miniature current bedding due to ripple-mark. The fossils are for the most part fragmental, and occur in small groups, suggesting re-sorting along a beach or on a sandbar. The following forms have been identified (the last four by Mr. Chapman) :—

Anthozoa.	*Cladopora* sp.
Asterozoa.	*Taeniaster* (?), sp. nov. aff. *spinosus* Billings.
Brachiopoda.	*Orthis* (*Dalmanella*) *testudinaria* Dalman. *Chonetes* sp. cf. *Coelospira* sp.
Pteropoda.	*Coleolus* cf. *aciculum* J. Hall.
Cephalopoda.	*Orthoceras* sp.

The assemblage, especially *Cladopora* and *Dalmanella,* which are characteristic, indicates that the beds are Yeringian (Upper Silurian) in age. Indeterminate fragments of plants were found in several places along the Little River east of Taggerty. No fossils were found in the south near Buxton, but the Silurian rocks are apparently continuous on the west side of the Acheron from Taggerty to Buxton, as is shown on the Geological Survey's map, and in part confirmed by Dunn (1907). The beds are lithologically quite similar in the north and the south.

In the north the fossiliferous beds are overlain unconformably by the Upper Devonian, and are faulted against the Cathedral Beds along an east-west fault line. This fault is pre-Upper Devonian, beds of that age not being displaced by it. In the south the relations with the Cathedral Beds are different, the two apparently forming a conformable series. The Buxton granodiorite–porphyrite (? Lower Devonian) is intruded, perhaps as a sill, into the typical Silurian sediments, which are only slightly metamorphosed. Quartz veins, in part auriferous, are associated with the granodiorite.

On the north side of the Little River, the dip is 58° to the south-south-west, and the same dip and strike were found in a small creek just to the north of the fault, on the northern slopes of the Cathedral Range. No other outcrops were found where a definite dip could be obtained (see, however, p. 180).

2. *The Cathedral Beds.*

The rocks—hard sandstones, soft sandstones, and shales—which constitute the Cathedral Range and Chapel Hill, form a triangular outcrop between the Blue Hills and the Acheron Valley, ending abruptly in the north against a fault line. On the evidence before cited (see p. 177), they were previously regarded as of Upper Palaeozoic age.

Field Relations.

Ferguson could find ". . . no clear contact . . . showing the relation of the Silurian rocks to the Cathedral sandstones." Furthermore he says, "On the east the sandstones join the fragmental porphyry formation at the Little River."

(*a*) At their northern termination the Cathedral Beds are brought against the typical Silurian rocks by an east-west fault. Huge monoliths of crushed and shattered sandstone occur along the fault line, and the strikes are locally contorted. The evidence of faulting may be traced a short distance to the east before being covered by talus, and the further extension of the fault to the east is inferred from the abrupt termination of the Cathedral Beds along the east-west line. Evidence as to the hade is indefinite, but the general dip of the Cathedral Beds (especially on Chapel Hill away from the fault line may indicate that the downthrow is to the south. No indication of displacement of the Upper Devonian beds by this fault was seen.

(*b*) East of Buxton, the relations are different. Traversing eastwards from Buxton, we notice that

1. The typical Silurian beds are intruded by the granodiorite-porphyrite.

2. The Silurian can be traced without apparent break to the foot of the Blue Hills, and there the dip and strike are the same as those of the Cathedral sandstones which occur close by, and have the same relations to the Upper Devonian as does the typical Silurian. The following observations are significant:—

(*a*) 1½ miles W.20°N. from Buxton, the Silurian beds strike N.32°W. dip 40° westerly (Dunn, 1907). Compare

(*a'*) About a mile northwards along the Cathedral Range from the Sugarloaf, Cathedral Beds strike N.25°W. dip easterly at 60°.

(*b*) 3 miles E.10°S. of Buxton, the Silurian beds strike N.30°W. dip easterly at 70° (Dunn, 1907). Compare

(*b'*) Southern end of the Cathedral Range, Cathedral Beds strike N.35°W. dip 65° easterly. Furthermore, the Cathedral Range shows a marked parallelism with the trend lines in the Silurian in the southern part of the area, where no faulting occurs.

3. Just east of the Sugarloaf, in a small creek, the relations between the Cathedral beds and the Upper Devonian rhyolites can be clearly seen. The latter, striking N.25°E., and dipping at 30° easterly, overlie the Cathedral Beds, striking N.35°W., dipping 65° easterly, with a strong unconformity. The basal conglomerate, though developed further north, is absent here; but that we are dealing with the base of the rhyolite is shown by the well-developed prismatic jointing, which disappears higher up in the flow, the numerous linearly arranged sandstone inclusions which lessen in number and lose their linear arrangement higher up, and the slightly vesicular nature of the flow, which elsewhere is devoid of vesicles. Further, there is no contortion of strikes or brecciation in the Cathedral sandstones, such as are found where these beds are faulted in the north. Similar relations hold everywhere at the edge of the Upper Devonian series, being especially well shown south-east of Chapel Hill, where the characteristic oscillation ripple-marked sandstones are overlain by the Upper Devonian basal conglomerate.

The pre-Upper Devonian age of the Cathedral Beds is thus established, and their conformability with the Silurian strongly indicated. In the absence of palaeontological evidence as to their more precise age, the author has placed them high in the Upper Silurian series.

Lithology.

Ferguson's original description is in the main correct, though, even after extensive search, the present author could find none of the "well-waterworn pebbles" mentioned by him, the largest particles found being only a few millimetres in diameter. The sandstones are very thick-bedded, and where not cross-bedded, are even-grained. The jointing is somewhat irregular, curved cracks often forming in the thick, even beds. When not strongly weathered the sandstones are red, but leaching of the outer few millimetres of weathered blocks produces a white skin. Ripple-markings, mud-cracks, current-bedding, and hardened clay pellets were found.

Along the Cathedral Range, subaqueous current ripple-marks occur, rarely. On Chapel Hill, however, ripple-marks of symmetrical shape, and formed by wave action (oscillation ripple-marks), occur in profusion in fine sandstones of lighter colour than the Cathedral sandstones. At some horizons the successive ripple-marked layers are separated by only fractions of an inch, and the lengths of the ripples from crest to crest (wave-length) remain fairly constant, averaging a little over an inch. The direction of propagation of the water waves which produced the ripples remained fairly constant, also. Examples were found of superimposition of the ripples in parallel and slightly inclined directions. No current-ripples (asymmetric) were found on Chapel Hill.

Mud-cracks are rare, but were found at the Sugarloaf, the north end of the Cathedral Range, and on Chapel Hill. The former two examples are in very fine, indurated sediment, a thin parting between heavy sandstones. The polygons are small, about six or eight inches across. The latter example (Chapel Hill) is in a thick sandy mud bed, which is cracked to a depth of about eighteen inches, the polygons ranging up to fifteen inches across. The edges are here turned down conspicuously.

Sandstones showing current-bedding were found at the Sugarloaf, but nowhere else. The current-bedded layers are usually bounded by plane surfaces, though a very few show curved boundaries. The slopes are fairly steep, especially in the thicker beds, whose thickness is up to three feet between the bounding planes.

Inclusions of very fine sediments similar to the material of the mud-cracked layers on the Cathedral Range are common there, but are absent in the oscillation ripple-marked sandstones of Chapel Hill. They probably represent clay pellets rolled into the sands by current action.

The interbedded soft sandstones and shales are grass-covered, and the only outcrops are blocks in the roots of fallen trees. The bed separating the two sandstones of the Cathedral Range is a soft chocolate sandstone, and differs from the more yellowish shales of Chapel Hill. No fossils were found in any of the Cathedral Beds.

The Cathedral Beds differ from the Upper Palaeozoic rocks with which they were formerly included, in the absence of the conglomerates which are so characteristic of the latter, as described by Howitt (1876), Murray (1877), Kitson (1899), and Teale (1920), the absence of interbedded lavas, and the absence of fossils. They also dip at a much greater angle than the Upper Palaeozoic rocks, except where these are faulted. The author considers that much more detailed work than was possible in the time available will be necessary to elucidate the very interesting question of the conditions under which the Cathedral Beds were deposited. He would point out, however, that—

1. The Chapel Hill beds resemble somewhat the Berea sandstones of North America in the profuse development of the oscillation type of ripple-mark, with a generally constant direction of propagation, the absence of current ripples, and the lack of fossils (Hyde, 1919).
2. The Chapel Hill and the Cathedral beds were not deposited under exactly the same conditions, as is shown by their different physical characteristics (see above).
3. In the Grampians sandstones, a thick series in which no fossils were found for many years, the few remains now known indicate a marine origin for the beds in which they occur (Chapman, 1917).
4. The absence of cut-and-fill structures and coarse materials, and the scarcity of muds and sun-cracked layers, as well as the extent and thickness of the beds, are against either a flood-plain or sub-aerial deltaic origin.

(?) LOWER DEVONIAN.

Intruded into the Silurian sediments at Buxton and to the east of Taggerty is a granodiorite-porphyrite, which is placed in the Lower Devonian by analogy with the other Victorian granodiorites, which are supposed to be of this age. Such granodiorites occur near Marysville, to the south of the occurrence at Buxton. The latter is much more extensive than the outcrop at Taggerty, being a long and narrow outcrop traced for two miles in a NNW. direction, and continuing still further to the southwards. The obvious relation of its outcrop to the trend of the Silurian near by, and its long, narrow outcrop, have led the author to believe that it may be a sill. The amount of metamorphism of the adjacent sediments is but slight, being merely an induration, with some silicification and development of muscovite. Quartz veins are associated with this intrusion, and these have proved auriferous to the south of the area considered.

The occurrences at Taggerty are very small, perhaps offshoots from a larger concealed mass. Of note is the occurrence in these rocks of numerous pink garnets, sometimes showing dodecahedral outlines but more often rounded by reaction with the magma. Cognate (basic) and foreign xenoliths also occur.

UPPER DEVONIAN.

Beds of this age were discovered, forming the top of the Blue Hills and the ranges east of the Sugarloaf, and formerly believed to be Lower Devonian dacites. The main development is a series of acid lavas (rhyolites) of undetermined thickness, which outcrop along the whole of the eastern boundary of the area studied. Basalts and sediments also occur. There are numerous flows, the lower ones being interbedded with fossiliferous lacustrine and fluviatile deposits of limited areal extent; but the main rhyolite is recognisable continuously for over seven miles along its western edge, and the further extent to the south was not determined. Through the courtesy of the Director of the Victorian Geological Survey, Mr. Baragwanath, and his officers, the author had the privilege of examining some specimens collected by Mr. O. A. L. Whitelaw from the Mount Torbreck region, some nine miles to the east of the Blue Hills. The specimens proved to be of extreme interest, as they revealed the presence of exactly similar rhyolites, both in hand specimen and under the microscope, in that area, associated with typical dacites (as developed near Healesville, in the Dandenong Ranges, and at Mount Macedon) of supposed Lower Devonian age. A porphyritic granitic rock, very similar to that found at Buxton, is also in close proximity. The problems of the extent of the rhyolites and their relations to the granitic rocks are thus opened up.

A generalized sequence of the Upper Devonian is as follows:—

6. Rhyolite α (main flow, very thick).
5. Rhyolite β (small flow, in the north).
4. Basalt (in the north and south only).
3. Sediments (sandstones and shales in the north, bedded tuffs and volcanic breccias in the south).
2. Basal rhyolite.
1. Basal conglomerate (in the north).

The absence of the basal beds in places is due to their development only in the valleys of the Upper Devonian land surface.

They are overlapped by the main rhyolite flow, and where this rests on the Silurian directly, the upper Devonian land was high, so that the Sugarloaf was probably an upstanding peak then, as now (see Section E.-F., Fig. 1).

1. *The Basal Conglomerate.*

This extends uninterruptedly for nearly four miles along the Blue Hills, east of Chapel Hill. It is rather variable in thickness, reaching a maximum of about ten feet in the central part, and thinning out towards the north and south, where it is absent. The

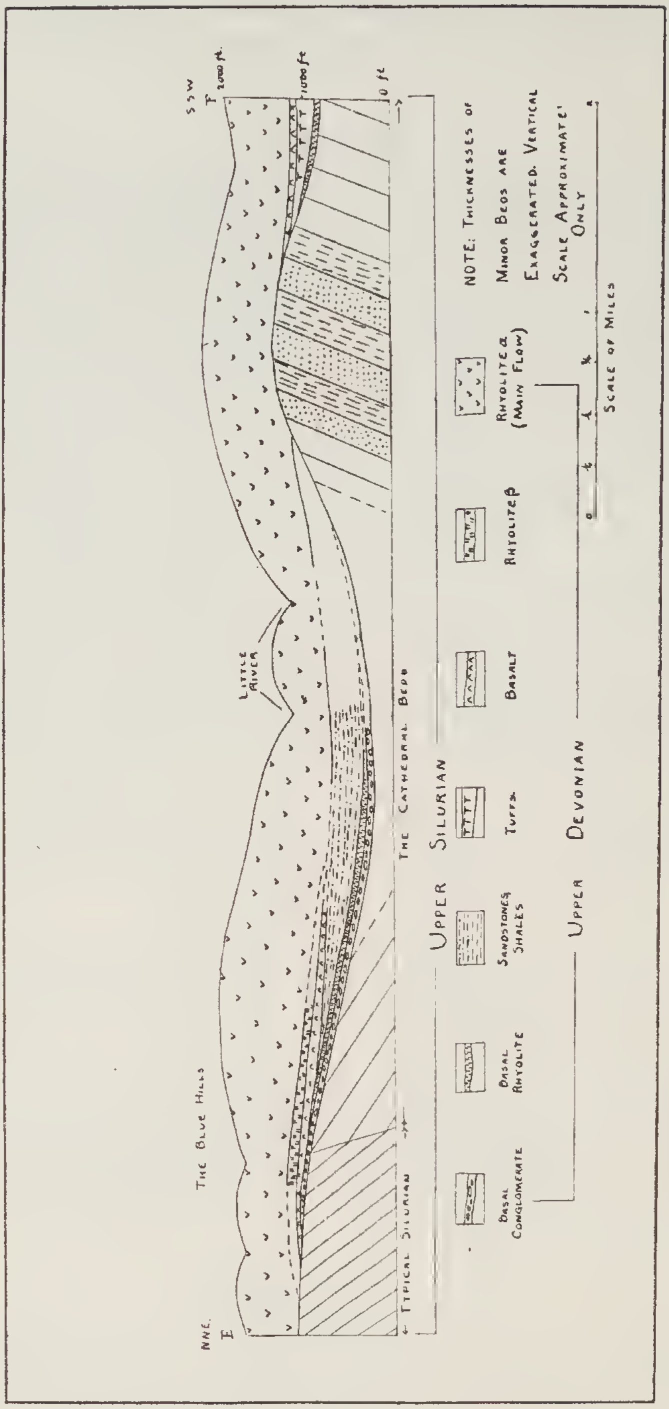

FIG. 1.—Diagrammatic section along the crest of the Blue Hills, parallel to the edge of the Upper Devonian outcrop.

coarseness varies in a like manner, the boulders in the centre being larger than elsewhere, reaching a foot or more in diameter. Some pebbles are well rounded, others flat and with the edges rounded off. They consist entirely of coarse sandstones, probably derived from the Cathedral Beds, and resemble fluviatile (valley-plain) deposits.

2. *The Basal Rhyolite.*

Locally, rhyolites of relatively small extent and thickness overlie the basal conglomerate, or rest directly on the Silurian where this is absent. These rhyolites generally show prismatic and platey jointing, and are lighter coloured and more weathered than the main flow. They are also more calcic, containing less free quartz and more plagioclase felspar (see p. 192).

3. *The Sediments.*

The basal flows of rhyolite apparently blocked the Upper Devonian streams, so that lakes were formed in which yellow and red sandstones, and red, blue and green shales were deposited. These sediments have yielded a fish fauna and remains of plants. The following forms occur:—

Ostracodermi.	*Bothriolepis gippslandiensis*, sp. nov.
Dipnoi.	*Eoctenodus microsoma*, gen. et sp. nov.
	Holonema cf. *rugosum* Newberry, 1889.

This assemblage is a typically Upper Devonian one (see p. 198).

Numerous round impressions in the fossiliferous blue shales probably represent bubble impressions, the gas coming from the decomposition of the inclosed organisms (Twenhofel, 1921, 1926, p. 289). Round the organic remains, especially the plants, and along joint planes, the blue shales are buff in colour. The jointing, especially in the sandstones, is much less regular than in the Silurian beds which underlie the Upper Devonian.

East of Buxton, bedded tuffs and volcanic breccias overlie the basal rhyolite, and underlie the basalt and main rhyolite. The tuffs are of two kinds, one a blue-black, well-jointed, compact rock, grading with increased size of its component particles into the volcanic breccias, and the other a light, chocolate, poorly-jointed, fine-grained rock. Both are products of the basic igneous activity.

The volcanic breccias compare almost exactly in hand specimen and microscopically with Teale's "basal beds" from the Mt. Wellington area, labelled by him "basal breccia." In that area the relations of these beds were not clear, but at Buxton they are evidently part of the basal beds of the Upper Devonian series, as thought by Teale to be the case. Above them comes the basalt to which they are undoubtedly related.

4. *Basalt* (pp. 191).

Very dense, fine-grained, hard blue-grey basalts occur fairly constantly above the sediments and below the main rhyolite.

They are occasionally absent, as at the Sugarloaf and in the extreme north. At their farthest northerly occurrence they rest directly on the basal conglomerate, without any intervening sediments. There they are very amygdaloidal at the base, the amygdales being filled with chlorite and chalcedony, and there are small amygdales in most of the basalt sectioned from higher up in the flow. In other parts of Victoria the basalts are interbedded with the rhyolites, and always occur " consistently higher in the series than the Wellington rhyolites " (Teale, 1920). Although the name " melaphyre " has usually been applied to similar rocks by workers in other areas, the author feels that in view of their relatively fresh state, the term basalt is most suitable in the present case.

5. *Rhyolite β* (pp. 190).

In the north, a small flow of a black aphanitic rock with small, clear quartz crystals occurs above the basalt and beneath the main rhyolite. It is, again, less acid than the main flow.

6. *Rhyolite α* (pp. 188).

The most constant of the Upper Devonian rocks is the main rhyolite. Its thickness must be very great, though this was not determined, only the lower edge of the flow being examined. Its coarseness of grain led it to be identified as granite by the early surveyors.

The problem of the separation and distribution of the Upper Devonian and Lower Carboniferous series in South-Eastern Australia has long been a vexed one, and the discovery of the fish remains at Taggerty serves to give some definition to the data. Not only as regards structure and field relations, but also both macroscopically and microscopically, the rhyolites, " melaphyres," tuffs, conglomerates, shales and sandstones in the Cathedral district compare with similar rocks in the Upper Palaeozoic belt in Eastern Victoria, and the growing ideas as to their Upper Devonian age are strengthened. It should be noticed that the Taggerty fishes occur in beds stratigraphically beneath the main rhyolite flow, while many of the Lepidodendron sandstones in the great Upper Palaeozoic belt occur well above this flow, as at Mt. Wellington.

PLEISTOCENE (?) TO RECENT.

Deposits of greater age than the alluvium of the river valley-plains are represented in the alluvial fan from the Blue Hills, east of Taggerty, and the numerous alluvial cones and piedmont alluvial plain on the western slopes of the Cathedral Range. The creek which enters the Little River after flowing west past Andrews' house, aided by smaller streams, both tributaries of itself and of the Little River, has built an extensive alluvial fan. Owing to the removal of the lower edge of this by the Little

River, these streams are all now incised into the fan. It is composed of boulders, grading downwards in size to the individual quartz grains weathered from the rhyolites. The water-table is everywhere near the surface, as is shown by the numerous seepages which occur, both on its surface and more especially along its lower edge, where it is terraced by the Little River. The soil is rich, and the abundance of water and sheltered position make it valuable as farm land.

The talus produced by the rapid erosion of the Cathedral Range has formed extensive and very thick deposits between that range and the Acheron River. The numerous small wet weather streams which flow westwards down the escarpment face have each built a steep alluvial cone, and the coalescence of these has produced a very thick, continuous sheet of sediments. The streams which produced the sheet are now incised into it, because of the terracing of the lower edge by the Acheron. These deposits began to accumulate when the Cathedral Beds were exposed, in the process of dissection of the peneplain which was developed over Victoria in early Tertiary time. The date of the deformation of this peneplain is uncertain, but it is very probable that some of the above described deposits are at least as old as the Pleistocene.

The Acheron and Little Rivers and many of the smaller streams have alluvial flats, composed mainly of coarse boulders with interstitial fine silts. These flats are often swampy, especially in the upper reaches of the Little River. There, also, perfect small examples of alluvial cones are developing at the mouths of small streams from Chapel Hill. These cones have developed on top of the river alluvium since the last big flood, as they are unmodified by the river, the streams which formed them wandering indiscriminately over their surfaces.

SUMMARY.

After the deposition of the Upper Silurian beds in shallow epicontinental seas (and perhaps other environments in part), they were compressed in Siluro-Devonian or Lower Devonian times, into a series of large folds. Probably in the Lower Devonian, associated with the final earth movements, a large sill or dyke of granodiorite was intruded in the south, and some smaller apophyses in the north. Before the Upper Devonian, normal faulting occurred. Owing to the acceleration of erosional processes consequent on the high relief imposed by the fold movements, Lower and Middle Devonian times are represented by an unconformity. Continental deposits accumulated in the Upper Devonian in lakes formed by the dislocation of the drainage system by small flows of rhyolite. In late Upper Devonian time basalts and huge masses of acid lavas were extruded. Subsequently, the region was subjected to pressure from ESE. and WNW., producing the present strikes and dips of the Silurian and Devonian rocks.

From the Upper Devonian to the Pleistocene, the resultant of earth processes has been erosion, and no deposits are found of an age intermediate between these two periods. In the early Tertiary a peneplain was produced, which later suffered uplift, so that it is now in process of dissection. Locally, continental deposits of Pleistocene and Recent age were produced, and these are even now being removed by the streams.

Petrography.

(The numbers in square brackets refer to slides in the collection at the Geology School, University of Melbourne.)

Rhyolite a. Cordierite Nevadite.

(Pl. XVII., Fig. 1.) [2244; 2245.]

Macroscopically and microscopically, this flow is extremely constant over the seven miles studied. It is a compact rock with dark cryptocrystalline groundmass and very numerous phenocrysts, a few millimetres in diameter, of clear quartz and cloudy felspar, usually white, but sometimes pink, and an occasional biotite. Fluxion structure is developed only along the lower edge, and even then is infrequent, though some beautiful specimens were found, coloured by weathering. Throughout the whole flow to some extent, but becoming more numerous towards the base, are xenoliths of sandstone and shale. Where the flow rests on the Cathedral sandstones the sandstone xenoliths are more numerous, and where it rests on the more shaly typical Silurian beds, the shale xenoliths, often altered to a spotted shale and always indurated, are more frequent. A few xenoliths of the basalt were found.

Chemical Composition.

	1.	2.	3.
SiO_2	74·72	74·39	78·64
Al_2O_3	13·05	14·28	9·85
Fe_2O_3	0·52	0·52	0·54
FeO	1·42	1·09	2·00
MgO	0·41	0·27	0·10
CaO	0·66	0·24	0·80
Na_2O	3·62	2·78	2·03
K_2O	4·31	5·33	5·16
H_2O+ . . .	0·61	0·22	0·40
H_2O- . . .	0·13	0·56	0·14
CO_2	0·08	—	—
TiO_2	0·16	0·29	0·67
P_2O_5	0·38	tr.	tr.
MnO	—	n. det.	—
F	n. det.	n. det.	n. det.
Cl	tr.	n. det.	n. det.
Total	100·07	99·97	100·33

1. Rhyolite, Blue Hills, Taggerty. Analyst, E. S. Hills.
2. Rhyolite, Archer's Lookout, Narbethong, Analyst, N. R. Junner.
3. Rhyolite, Mount Wellington. Analyst, E. O. Thiele.

Norms and Classification.

	1.	2.	3.
Quartz	35·58	36·30	44·52
Orthoclase	25·58	31·69	30·58
Albite	30·39	23·63	17·29
Anorthite	0·56	1·11	2·22
Corundum	2·24	3·47	—
Hypersthene	2·85	1·76	2·68
Magnetite	0·70	0·70	0·70
Ilmenite	0·30	0·61	1·22
Apatite	0·93	—	—
Class—	Persalane	Persalane	Persalane
Order—	Quarfelic	Quarfelic	Quarfelic
Rang—	Peralkalic	Peralkalic	Domalkalic
Sub-Rang—	Sodipotassic	Sodipotassic	Do-sodipotassic
Magmatic Name—	Alaskose	Alaskose	Mihal-Tehamose

Under the microscope the quartz phenocrysts are seen to be rounded and embayed, often very deeply. The felspar is microperthitic orthoclase, the included felspar being quite abundant. It has a greater refractive index and double refraction than the orthoclase, and shows polysynthetic twinning. The high soda (and low lime) content of the rock points to the perthitic intergrowth as being albite or oligoclase-albite. The orthoclase phenocrysts are nearly as numerous as those of quartz, and about the same size; they show some rounding of the corners and edges, and are very fresh. Small plagioclase phenocrysts are of infrequent occurrence. Though the maximum extinction on the albite twinning lamellae ranges up to 26° in these, the refractive index is less than that of quartz. They may be oligoclase-andesine. A small amount of biotite is present in all sections, while in one it is more abundant as small flakes in a rather coarser groundmass than usual. Colourless cordierite, fresh in part, but often altered to muscovite (pinite) or almost isotropic chlorite, is also present. One section exhibits a trilling, but often all that remains of the original mineral is a brown micaceous or chloritic mass. Small blue tourmalines occur as single crystals and as radiating aggregates, and are often associated with the material filling the embayments in the quartz crystals. Small black specks in the groundmass are probably ilmenite.

The groundmass is micro- to cryptocrystalline, and always shows well-developed flow structure, the contorted lines curving round the phenocrysts of quartz and felspar, which are not arranged linearly. Biotite crystals curve with the flow lines, and wrap round the quartz and felspar. On solidification, the groundmass was evidently a glass, varying in composition from point to point. Some bands are coarser than others, and consist of colourless mica and material with undulose extinction and fairly high double refraction, which is probably a soda felspar. Other bands are cryptocrystalline, much of the material having a higher refractive index than quartz. Again, in some cases biotite flakes, quartz, felspar and colourless mica can be recognised, and occasional microspherulitic aggregates occur. Apatite needles are seen in the quartz and orthoclase, but the high norm of this mineral indicates that some is present in the groundmass.

Junner (1914) has described rhyolites from near Narbethong, which resemble very closely the above rock. He mentions, among other things, the occurrence of blue tourmaline, corroded quartz, and perthitic orthoclase. The analyses show an evident similarity also.

Rhyolite β [2246].

This is a black aphanite with small, clear quartz crystals and turbid felspar. Under the microscope it is seen to be crowded with angular fragments of quartz and felspar, which appear to represent broken crystals. This might be due to continuation of the process of embayment till the crystals are eaten through, or (Rosenbusch; Osann, 1923) to rapid cooling of the rock giving rise to shattering of the crystals. The felspar is both plagioclase and orthoclase, the former giving a maximum paired extinction of 22° on the albite lamellae, having a lower double refraction than that of quartz, and a high refractive index. It is thus andesine. Carlsbad twinning is sometimes shown as well as the albite, and zoning is well developed. The orthoclase is in general untwinned, and is about equal in amount to the plagioclase. A few fragments of pink garnet, and biotite flakes are present. The groundmass is cryptocrystalline, and micro-fluxion structure, due to an originally heterogeneous magma liquid, is sometimes seen. Apatite, inclosed in quartz crystals, is a common accessory, and veinlets of epidote and zoisite traverse the rock. A somewhat clastic appearance is shown under the microscope, and cherty-looking aphanites from near Narbethong have been described as silicified tuffs by Junner (1914). However, in the present case, the evidence points rather to solidification with sudden chilling of a lava flow, perhaps under water. Thus,

(*a*) Some of the shattered phenocrysts have not been separated, and the fragments as seen may be imagined as fitting together.

(*b*) The micro-fluxion structure shows that the groundmass is not clastic but igneous, representing a devitrified glass.

(*c*) The rock does not contain lapilli, and is quite distinct from the pyroclastics which occur at Buxton.

(d) The epidote and zoisite veinlets may be due to the action of caught up and heated water on the groundmass of the rock.

Small (microscopic) xenoliths of sandstone and basalt occur, but are not large enough to be seen in hand specimen.

An analysis of the rock gave the following result:—

SiO_2	70·81
Al_2O_3	15·73
Fe_2O_3	0·76
FeO	1·97
MgO	1·30
CaO	1·68
Na_2O	1·75
K_2O	5·44
H_2O+	0·54
H_2O-	0·10
CO_2	—
TiO_2	0·09
P_2O_5	0·22
Total	100·09

Norms and Classification.

Quartz	33·48
Orthoclase	32·25
Albite	14·67
Anorthite	6·95
Corundum	4·39
Hypersthene	6·47
Magnetite	0·70
Ilmenite	0·15
Apatite	0·47

Class—Persalane
Order—Quarfelic: Columbare
Rang—Domalkalic: Alsbachase
Sub-rang—Dopotassic: Mihalose

Analyst—E. S. Hills.

Basalt [2250].

This is a hard, dense, fine-grained, grey rock. Under the microscope small phenocrysts of pale green augite are common, and these are sometimes glomeroporphyritic. Labradorite also occurs as phenocrysts and felted laths in the groundmass. Small rectangular crystals of black iron oxide are numerous, and carbonates are present in the groundmass. Irregularly shaped vesicles are scattered throughout, and contain mainly chalcedony, though in some concentric bands of chlorite are seen.

The rock is moderately fresh, but some chloritization of the pyroxenes has gone on, and an occasional large felspar shows complete decomposition to colourless mica, though others are quite unaltered. Local variations are mainly textural, one section showing macroscopic crystals of iron oxide, but no plagioclase or augite phenocrysts. In the north the flow is amygdaloidal, the amygdales being about a quarter of inch in diameter, and very numerous. They are filled with chalcedony and chlorite.

Volcanic breccia [2248].

This rock is dense, and contains numerous lapilli of grey-black altered basalt, set in a lighter-coloured matrix. The lapilli do not exceed an inch in length, and they grade downwards to small grains in the tuffs. Under the microscope the lapilli are seen to be of porous altered basalt, the vesicles being filled with chlorite and chalcedony, also epidote and carbonates. Numerous rhomb-shaped sections of an altered mineral occur, composed of serpentine and showing irregular cracks along which iron oxide is segregated. These are almost certainly altered olivine, and they are present in both the lapilli and the groundmass, in the latter case as fragments bounded by the curved fracture lines. The absence of olivine in the basalts above the tuffs is interesting, and indicates that the augite was produced by the reaction of the olivine with the magma. Small iron oxide crystals are numerous. In the groundmass of the rock detrital quartz occurs, with fragments of altered olivine and small fragments of the basalts.

Basalt tuffs.

The finer grained pyroclastics have weathered very strongly, giving chocolate and purple soft, light and friable material. The breccias and tuffs are both well bedded and jointed.

Basal rhyolite [2247].

The flows at the base of the series are less acid than the main rhyolite. They are light or dark grey, with a few quartz crystals and abundant tabular felspars set linearly in a fine-grained groundmass. Under the microscope, altered felspar and biotite and embayed quartz phenocrysts are seen. Acid oligoclase apparently predominates over orthoclase, though the alteration makes determination uncertain. Numerous blebs of limonite are apparently pseudomorphous after magnetite, the original parallel growth of the cubic crystals being readily made out. The groundmass is microcrystalline to cryptocrystalline.

Granodiorite-porphyrite [2249].

In hand specimen this rock shows moderate sized phenocrysts of quartz, white felspar and biotite, set in a finer groundmass. Much fissured pink garnets occur sporadically. They show dodecahedral outlines and are about half an inch in diameter. A few biotite-rich " basic segregations " were seen, and some xenoliths of country rock, altered to hornfels.

Under the microscope, the quartz is seen to be embayed. The rock weathers readily, all the specimens examined having cloudy felspars. The plagioclase gives a maximum extinction of 20° on the albite twin lamellae, and is andesine. Orthoclase is subordinate in amount to the plagioclase. The biotite is bleached and chloritized, and has numerous inclusions of zircon as elongated crystals arranged along the cleavage planes. Some zircon and apatite occur in the groundmass, which is composed of quartz, biotite and felspar. The latter is in part twinned plagioclase of lower refractive index than that of quartz, probably oligoclase, and in part untwinned felspar of low double refraction and lower refractive index than that of quartz, probably orthoclase. The cracks in the garnets are filled with chlorite and inclusions of biotite and apatite are present.

The Buxton and Taggerty granodiorites are exactly similar both macroscopically and microscopically, except that in a slide of the latter a fairly large piece of blue tourmaline showing radiate structure occurs.

Palaeontography.

Fish and Plant Remains from Taggerty.

Plantae.

The fragmental plant remains found in the blue shales which yielded the fishes described below are incapable of exact definition. Some are narrow, alternately branching stems, with indications of a relatively large central woody (?) cylinder. Miss I. Cookson, who examined these remains in the hope that they might be Psilophytales, says that they yield no indication of structure on treatment with hydrofluoric acid, and are indeterminate.

Others are unbranched and show indications of longitudinal ribbing, both coarse and fine. These resemble the "*Cordaites*" *australis* McCoy, from the Avon River beds.

Class PISCES.

Sub-class DIPNOI.

Order CTENODIPTERINI.

Family CTENODONTIDAE.

Eoctenodus, gen. nov.

Eoctenodus microsoma, gen. et sp. nov.

(Plate XVIII., Figs. 2-7; Text-fig. 2, Nos. 1, 2, 3, 5, 6.)

Type Material.—Dentaries of mature and immature individuals. Parasphenoid and median occipital bones of mature individual. Scales. Bones of the shoulder girdle.

The Palate.—Specimen JA. Impression of the lower surface of the left dentary (pterygopalatine with attached dental plate), preserved in fine blue shale, and cleaned by weathering. Dental plate elliptical, 0·55 cm. wide and 1·50 cm. long, bearing 10 denticulate sub-parallel ridges. The ridges increase in size from 1 to 10 (see Text-fig. 2, No. 1), and the denticles increase in size from inside to outside, being directed apically outwards.

Pterygopalatine. Maximum length 1·85 cm., maximum width 0·90 cm. (Text-fig. 2, No. 1, and Pl. XVIII., Fig. 7). JA shows the usual transverse crack across the alate extremity, but even so a distinct downward turn of this part is noticeable. No scar is present on the inner edge such as has been described for *Sagenodus* and *Ctenodus* (Watson and Gill, 1922-24), due to overlap of the parasphenoid. In *Eoctenodus* the latter bone apparently abutted against a ridge on the pterygopalatine. As is usual, the symphysis of the left and right pterygopalatines was weak, the three specimens found being separate. Both extremities of the alate portion are rounded and the lateral edges smoothly curved.

Specimens JE 3, JB 1. Mould of the left dentary, preserved in the same blue shale as JA, but unweathered. General description as for JA, but 9 ridges only present on the dental plate, and the whole somewhat smaller in size, indicating a younger individual. Differs also in that the ratio of breadth to length is greater than in JA. Pterygopalatine unbroken, and showing marked downward curving of the extremity. Thickness of dental plate at outer edge 1·25 mm.

Specimens C. XVII., *a,b*. Mould of left dentary of a very small form, probably the young of *Eoctenodus*. The dental plate measures only 0·4 cm. by 0·2 cm., and bears eight ridges, strongly denticulate, and all slightly concave forwards. Pterygopalatine relatively large compared with the dental plate, and of a peculiar shape (see Pl. XVIII., Fig. 2). Four denticles present on the larger ridges, directed apically outwards.

Specimens JFA, JF. Mould, in the same matrix, of a parasphenoid, the posterior shaft being incomplete. Length 3·5 cm., width 1·4 cm. JFA shows the impression of the cranial (dorsal) surface, and a plasticine squeeze reveals a ridge round the anterior part of the lozenge, which may have abutted against a similar ridge (*vide ante*) on the buccal surface of the pterygoids. Posteriorly a central ridge extends from the centre of the main lozenge into the attenuated basisphenoid. A peculiar median pit is situated on the anterior part of the lozenge. (Pl. XVIII., Fig. 5; Text-fig. 2, No. 5).

Cranial Roof Bones.—Specimens C.MO 1, 2. Mould, in the same matrix, of a median occipital, incomplete. Anterior process relatively large and sharply defined. Estimated length (of median occipital) twice the breadth. One surface smooth (outer ? surface), and bearing only slightly developed radiating ridges, the other, of which only the anterior part is preserved, bearing finely sculptured lines, radiating from the centre of the bone. Maximum thickness, 1·5 mm. Length of anterior process 8 mm., breadth of bone about 2·0 cm.

Specimen JD. Impression, in the same matrix, of a circumorbital (?) bone. 7·8 mm. by 4 mm., 1 mm. thick. It shows ridges radiating from a central rosette, and is bevelled along the two long edges, the surfaces of the bevel being roughened.

The Shoulder Girdle.—The Clavicle. Specimen C.C. Mould, in the same matrix, of the upper surface of the right clavicle. Shaft long and narrow, 2·4 cm. long, 0·6 cm. wide, tapering at the articulating end, which bears a well developed ridge and hollow. Head imperfectly preserved, but apparently not very long. The end of the shaft is cracked across and slightly displaced, and this may indicate that it has been flattened from a twisted shape.

The Cleithrum. Specimens C XVIII. *a,b.* Mould, in the same matrix, of the left cleithrum. Outer surface with a very strong, central ridge, continued into a strong articulating process. Outer edge thickened. The bone is concave inwardly (the orientation being as given by Watson and Gill, 1922-24), but has been crushed in preservation due to collapse of the thick, spongy, bony structure, so that it is probably incomplete at the expanded end. (Pl. XVIII., Fig. 4; Text-fig. 2, No. 6.)

Bones, indet.—C XV. 1. Group of small cylindrical bones, associated with a longer linear group. These may be fin-bones.

2. Fine straight bones up to 1 inch long. These may be ribs or fin rays.

C.C. Strong, curved bone with expanded end, oval in section. This may be a neural spine.

Squamation.—Scales thin, often subquadrate with rounded corners and slightly concave edges. Internal structure of fine radiating ridges and furrows. Exterior smooth, marked by concentric growth lines, the centre of growth being excentric. The largest found measured 14·25 mm. by 12·75 mm. A few subrhomboidal scales were found, and these are smaller. Some show what is thought to be remnants of the lateral line (Pl. XVIII., Fig. 3.)

Relationships.—The dipnoan above described shows relationships with *Ctenodus* in some of the characters of the dental plate, with its sub-parallel ridges and elliptical shape, the well defined anterior process of the median occipital, the relatively large, thin, sub-quadrate scales and the bones of the shoulder girdle. It is related most closely to the small or moderate sized *C. interruptus* of the Lower Carboniferous, but is distinctive in the fewer ridges on the dental plate, and is separated from all forms of *Ctenodus* by its distinctive parasphenoid, which indeed serves to separate it from all other dipnoans. In size it probably approximated to that of *Phaneropleuron* and *Scaumenacia.*

Subclass OSTRACODERMI.

Order ANTIARCHA.

Family ASTEROLEPIDAE.

Bothriolepis Eichwald, 1840.

Bothriolepis gippslandiensis, sp. nov.

(Plate XVIII., Fig. 8; Text-fig. 2, No. 4.)

Type Material.—Impression of some plates of the head; impression of the external marginal of the right appendage.

Plates of the Head.—Specimen C.B. Impression, in fine, irregularly fracturing sandstone of the dorsal surface of some of the head plates of a *Bothriolepis.* Surface ornamentation of tubercles, fused more or less at their bases, producing distinctly

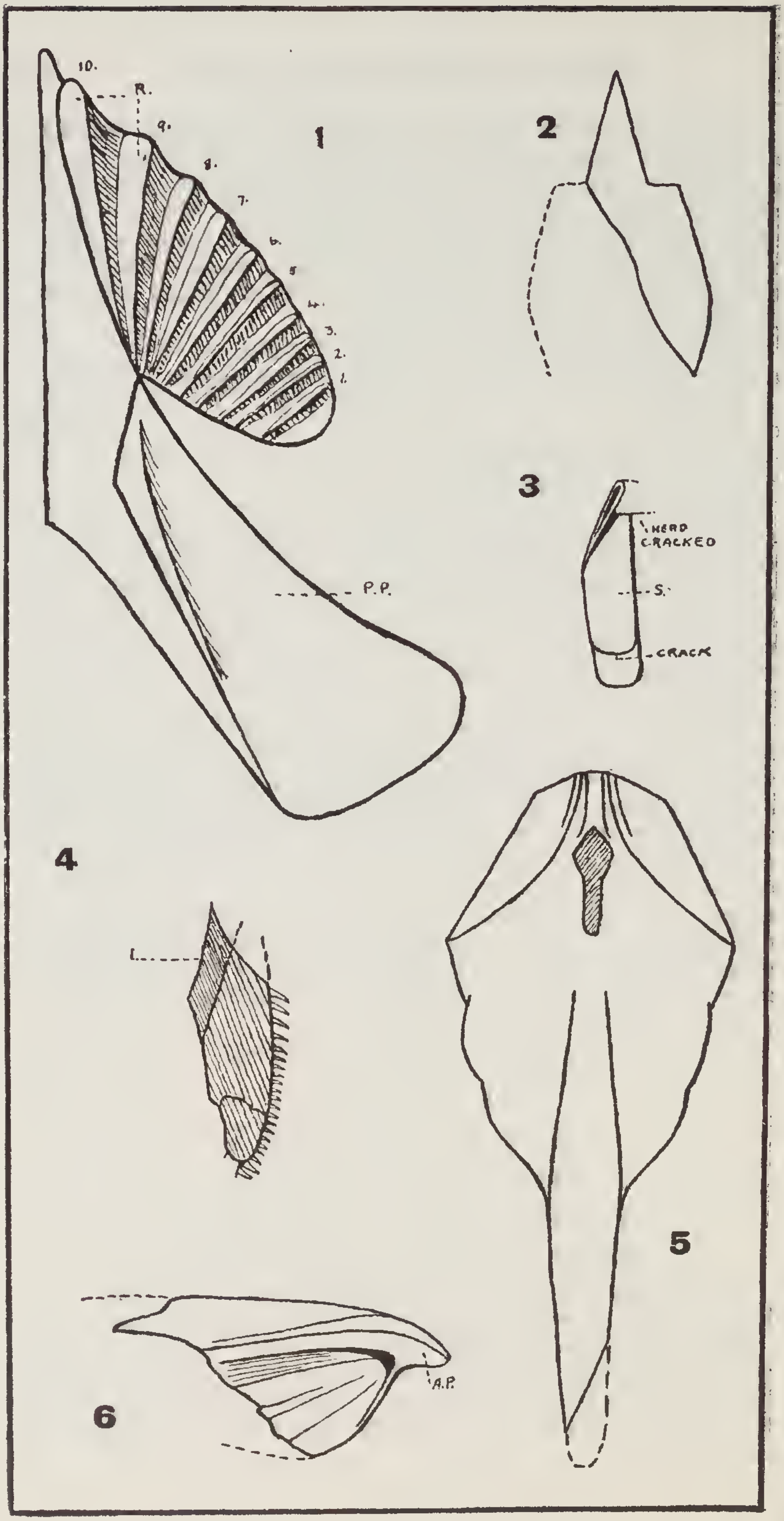

FIG. 2.

nodose ridges. The tubercles are often arranged linearly, e.g., parallel to the sensory grooves, which are united by a V-shaped commissure behind the orbits, and appear to bend round at the sides of the latter, instead of further anteriorly as in *B. canadensis* and *B. hydrophila.* (Pl. XVIII., Fig. 8.) Fracturing and displacement of the plates during preservation has, however, rendered the paths of these grooves outside the median occipital uncertain. The latter is wider than long, width 1·8 cm., length 0·9 cm. The post-median is missing, as are the orbitals.

Lateral Appendages.—Specimen C.L. Impression, in the same fine sandstone, of the external marginal plate of the right appendage. Marginal denticulations very strong. Ornament of fine parallel ridges, parallel to the line of junction with the interior marginal plate, and hence making an acute angle with the denticulate margin. Maximum width, 0·75 cm., exclusive of the denticles, length along the junction with the interior marginal 1·7 cm. The sudden constriction distally indicates that the distal end of the appendage is narrower than the proximal (Fig. 2, No. 6).

Relationships.—The above *Bothriolepis* resembles *B. canadensis* in the strongly denticulate margins of the appendages, but differs in the relatively short, compressed median occipital, in the disposition of the sensory grooves, and in size.

Sub-Class DIPNOI.

Order ARTHRODIRA.

Family PHYLLOLEPIDAE.

Holonema Newberry, 1889.

HOLONEMA cf. RUGOSUM Newberry, 1889.

Specimen C.H. Mould, in fine sandstone, of a plate of a placoderm fish, incomplete. Specimen measures 5 cm. by 2·5 cm. Ornament of radiating rugae, which are rounded, and in general equal in width to the separating grooves. One edge shows a slightly obtuse angulation. Maximum thickness shown 2 mm., which is near an edge, so that probably the plate was thicker in other parts. Compares almost exactly in pattern and size with the figure given by Newberry (1889, pl. xviii., fig. 4). "*Holonema rugosum.* Portion of lateral plate of carapace(?), natural size."

Fig. 2.

1. *Eoctenodus microsoma*, sp. nov. Dentary, drawn from a wax squeeze. R., Denticulate ridges (denticulations not shown), numbered from 1 to 10. P.P., pterygopalatine. ×4.
2. *Eoctenodus microsoma.* Median occipital, in part restored, showing anterior process. ×2.
3. *Eoctenodus microsoma.* Clavicle, drawn from a wax squeeze. S, shaft. ×1.
4. *Bothriolepis gippslandiensis*, sp. nov. External marginal of the right appendage. I, inserted area. ×4/3.
5. *Eoctenodus microsoma.* Parasphenoid restored. Cranial surface, from a squeeze. The shaded area is a pit. ×13/5.
6. *Eoctenodus microsoma.* The cleithrum, from a wax squeeze. A.F., articulating process. ×3/2.

Discussion.

The assemblage of fishes above described is a typically Upper Devonian one, and resembles in a remarkable way the suite of Chemung (Upper Devonian) age at Scaumenac Bay, Canada. In both localities we find a primitive small dipnoan, a coccostean form, and *Bothriolepis*, associated with plant remains (and in Canada, more fishes). This is interesting in view of the close resemblance Benson has shown to exist between the marine Upper Devonian rocks of New South Wales and the Chemung marine beds of the Eastern United States (Benson, 1922).

It is interesting to note that Dr. Smith Woodward writes (1904): "It may be said that . . . *Bothriolepis* and *Asterolepis* characterise the Upper Old Red Sandstone or Upper Devonian wherever it occurs—in Britain, Belgium, Germany, Russia, Spitzbergen, Greenland, Canada and the Catskills of New York." As the only other Upper Devonian fossils which had been found in Victoria up to the present were plant remains, some of which are of doubtful value, the present discovery serves to give some definition to our ideas of the Upper Palaeozoic succession in Victoria.

In conclusion, I wish to acknowledge my indebtedness to those who have freely given their advice and help during the progress of the research. To Professor Skeats especially, under whose direction the work was carried out, I must convey my thanks for his ready counsel on all occasions, his companionship for a few days in the field, and his criticism and encouragement. To Mr. Chapman, who has been my guide on all palaeontological questions, who determined some of the Silurian fossils, and who allowed me to use specimens in his care at the National Museum for comparison; to Miss I. Cookson, for help with the plant remains; to Mr. D. McCance, who smoothed out my paths in chemical analysis; and to Mr. J. S. Mann, who photographed the specimens figured in this paper, I must also express my thanks.

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EXPLANATION OF PLATES.

PLATE XVII.

Geological Map of the Cathedral District.

Notes on the Map.

The absence of contours renders the interpretation of this map a little difficult, because of the strong relief. The bending round of the outcrops of the Cathedral Beds at the north and south ends of the range is due to the form assumed by the beds on erosion. Between Chapel Hill and the Cathedral Range there is probably a fault, whose line is hidden under alluvium.

The wave-like edge of the talus along the Cathedral Range is meant to represent the numerous regularly developed alluvial cones descending from the escarpment.

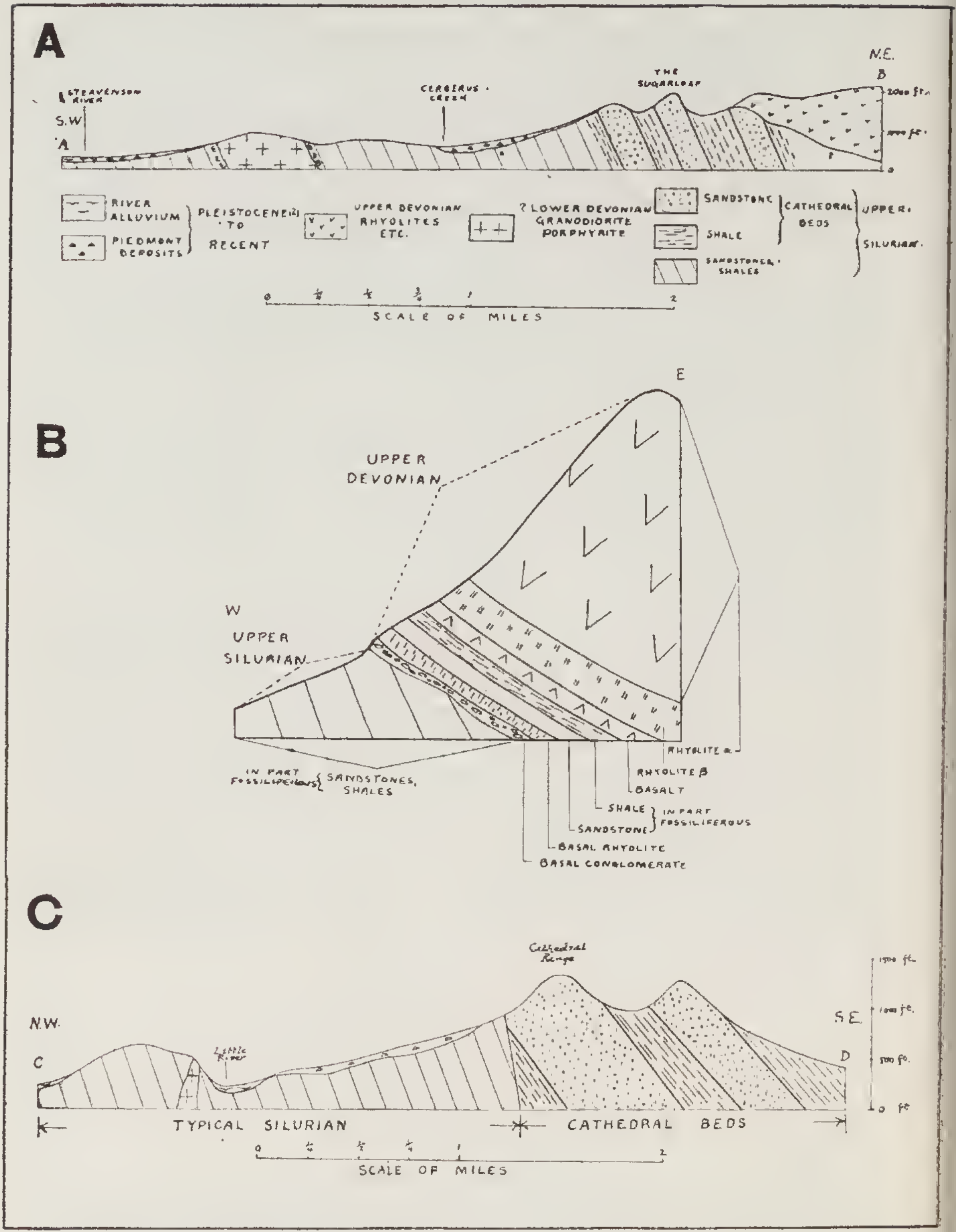

FIG. 3.—A: Sketch section along the line A B from SW. to NE. through the Sugarloaf, Buxton.

B: Diagrammatic section from west to east across the summit of the Blue Hills, showing the relations of the Upper Devonian and Silurian rocks in the north.

C: Sketch section along the line C D from NW. to SE., across the north end of the Cathedral Range, Taggerty.

GEOLOGICAL MAP OF THE CATHEDRAL DISTRICT